Electric Grid Disruptions and Extreme Weather

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US Disaster Reanalysis Workshop
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Asheville, North Carolina
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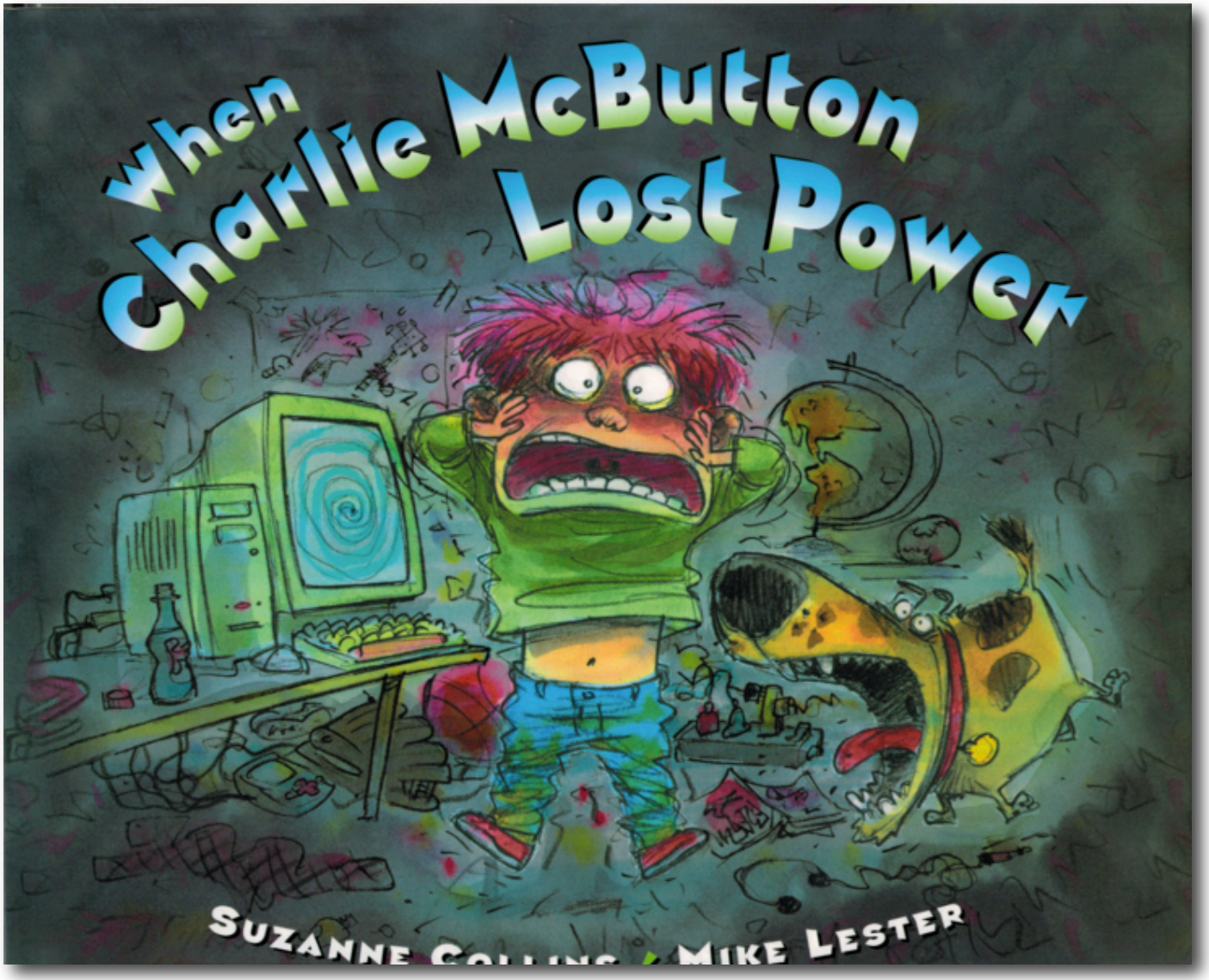
Even my kids are interested



Windstorm

Ice Storm

Sandstorm

Wildfire

Lightning

Drought

Hoover Dam turbines set for upgrade to cope with drought

April 19, 2010

The US Bureau of Reclamation has awarded a $3.4 million contract to Andritz Hydro Corporation to upgrade generating facilities at the Hoover Dam.

The Hoover Dam's water store, Lake Mead, has record low water levels because of the drought downstream

Andritz Hydro, which is based in Charlotte, North Carolina, will design and manufacture a new “wide head” turbine runner for the Number Eight generating unit at the power plant on the Nevada side of the Colorado River.

Drought & extreme temps

Drought could shut down nuclear power plants

Southeast water shortage a factor in huge cooling requirements

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Jason E. Miczek / AP

A man fishes next to the water outflows of the McGuire Nuclear Station near Lake Norman, N.C., on Monday. Lake Norman has dropped to about a foot above the minimum level needed for a backup system at the plant.

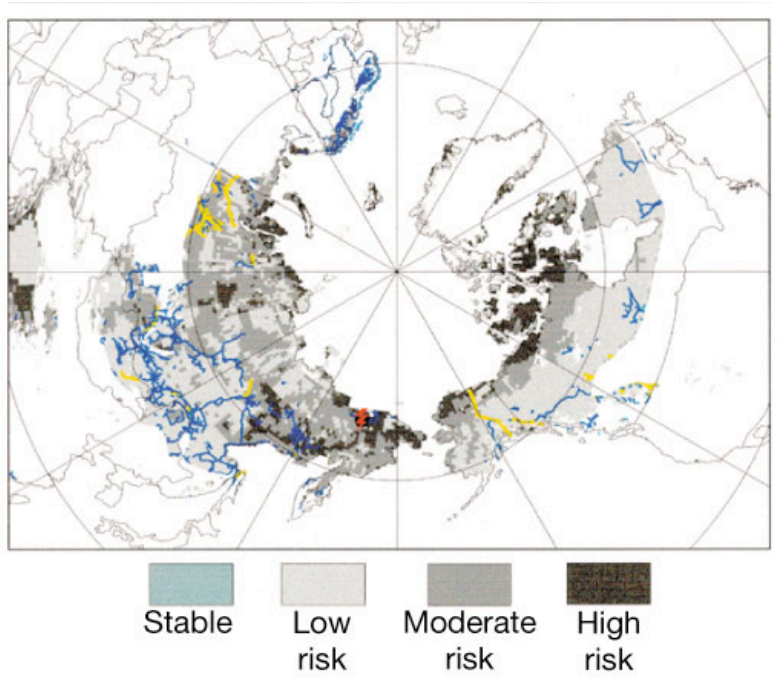
Flood

Permafrost disintegration

Electrical transmission (yellow)

Pipelines (blue)

Bilbino Nuclear Station (red)



Nelson, F.E., O.A. Anisimov, and N.I. Shiklomanov. 2001. "Subsidence Risk from Thawing Permafrost," *Nature* 410:889.

Grid disruptions are among risk managers' top concerns

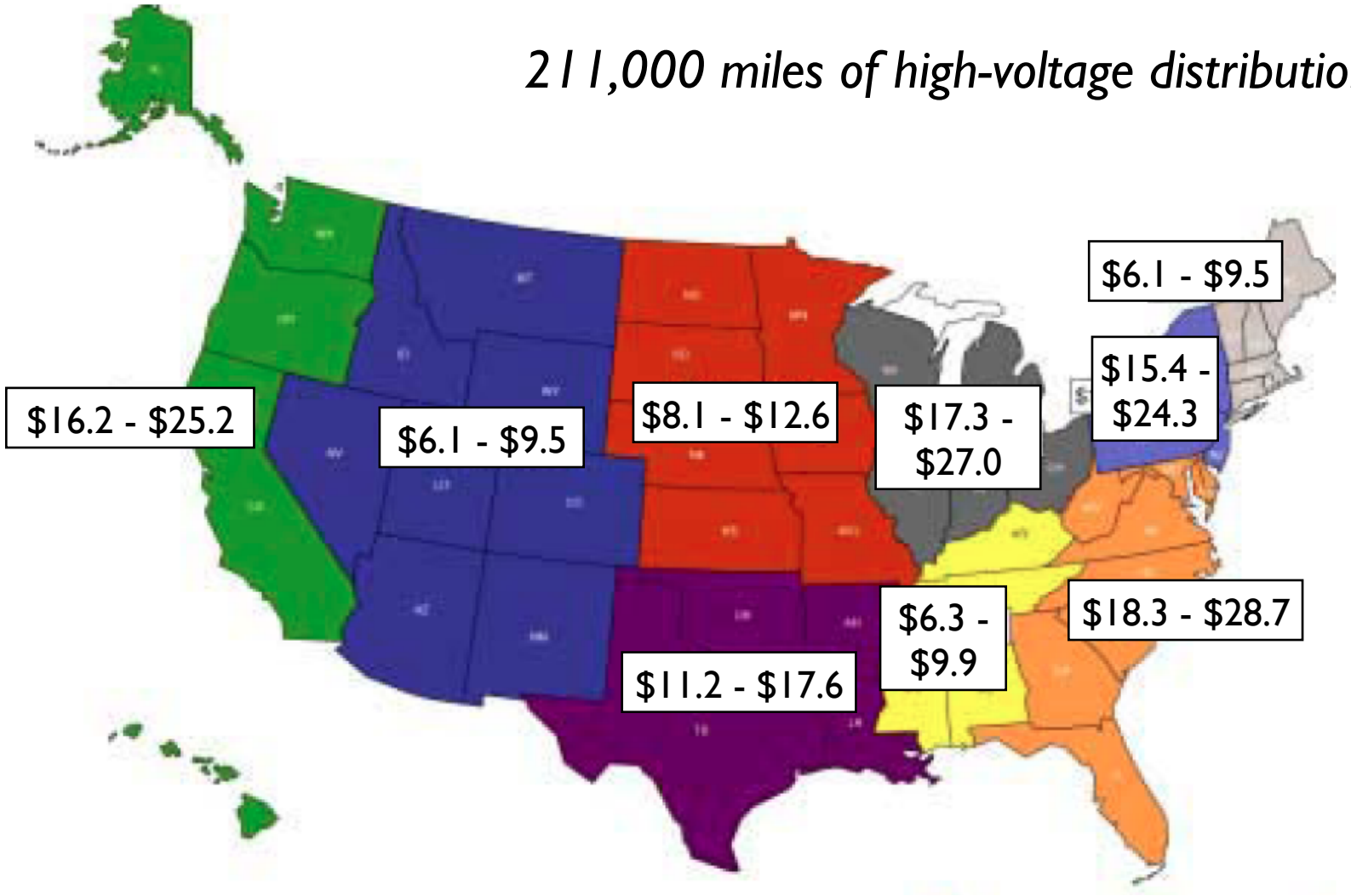
Hypothetical US Event	Total Cost ($B)	Insured Cost ($B)	Fatalities
Hurricane: Eastern Seaboard	74.6	45.1	85
Flood: Mississippi River	34.2	4.7	66
Oil Spill: Puget Sound	18	3.6	5
Terrorism: Chicago Loop	24	14	5000
Blackout: Ice storm in Northeast	17.1	2.7	?
Wildfire: Drought and temperature extremes in California	8.7	4.9	25
Industrial Accident: Petrochemical tanker fire in Houston	17-22	7-9	600
Cyber Attack: Fortune 1000	?	?	?
Pandemic: Mutated flu virus	?	?	200000
Earthquake: Los Angeles	100	27	400

From "Today's 10 Greatest Risks," analysis by Risk Management Solutions (RMS), in Risk & Insurance Magazine, April 15, 2004.

Northeast Ice Storm of 1998: Toppled 1000 transmission towers and 30,000 wooden utility poles. 1 million homes in Canada (100,000 people to shelters). 500k in New England (80% of Maine's population). 5M people w/o power. $2.6 billion in business losses and electrical infrastructure damages

BASELINE: $104-$164 billion annual costs of power outages in US, of which half in industrial sector & digital economy

211,000 miles of high-voltage distribution lines



Source: Primen. 2001. "The Cost of Power Disturbances to Industrial and Digital Economy Companies." Prepared for the Electric Power Research Institute. 98pp.

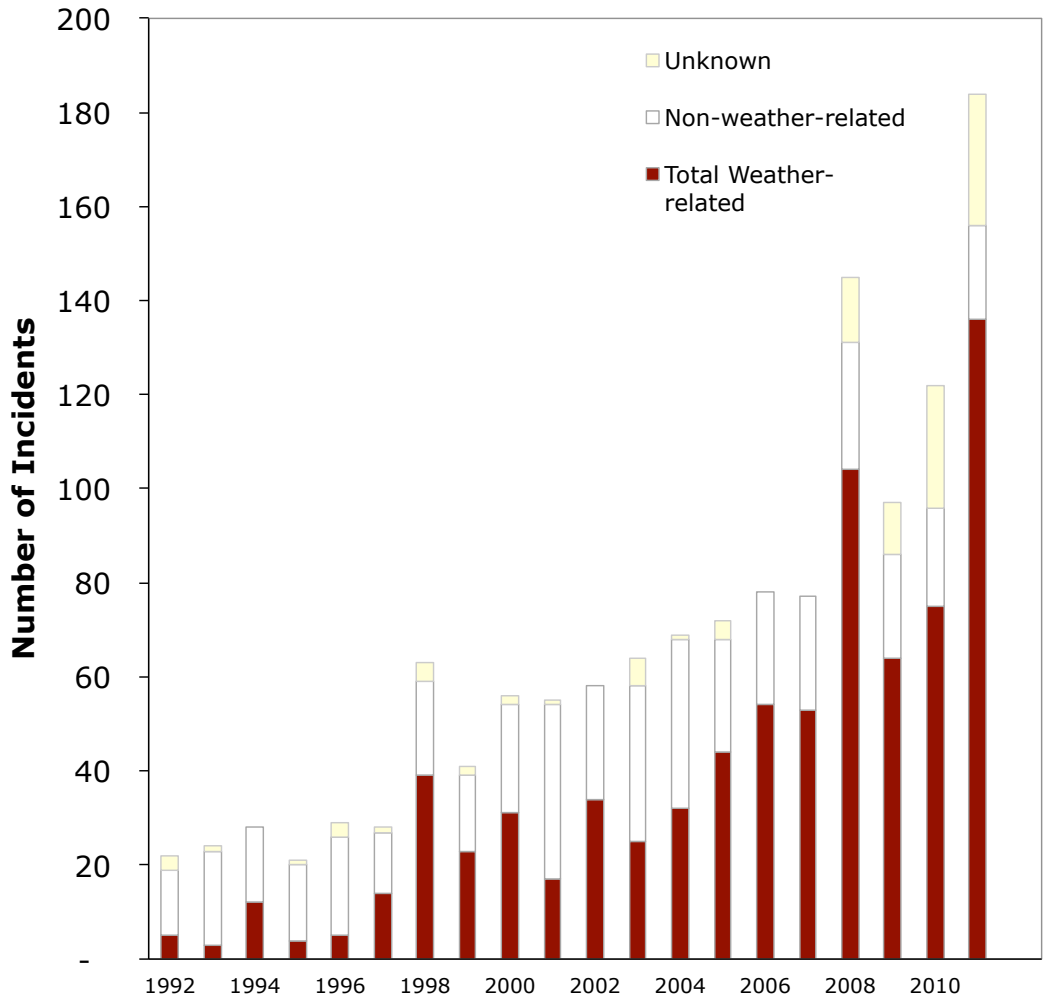
Trends

Appendix C — Disturbances, Demand Reductions, and Unusual Occurrences

(Analyses of the items in boldface are included in this report.)

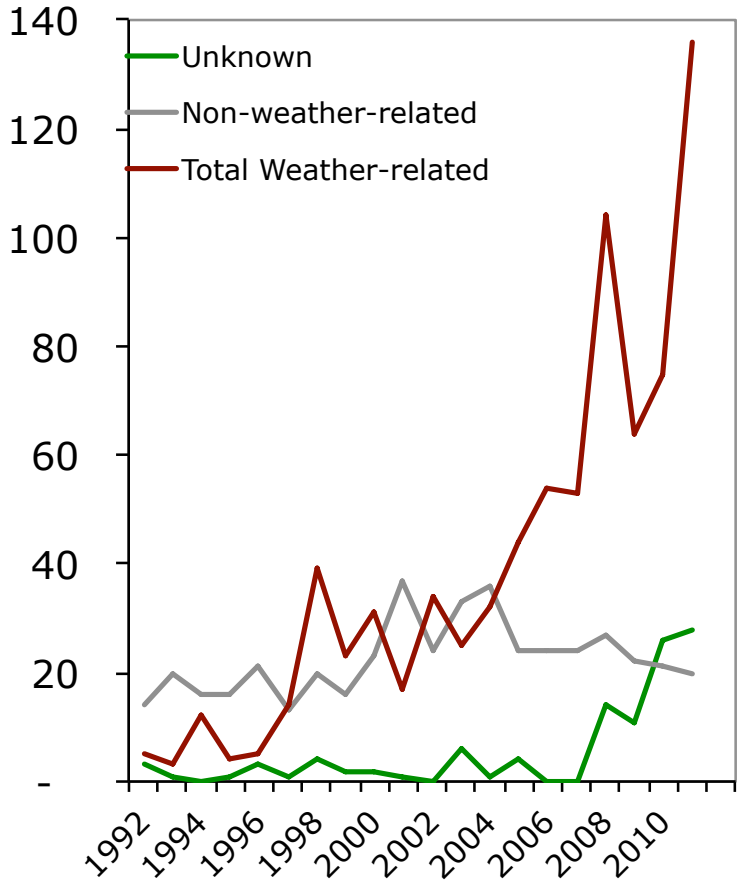
Date	Region	Utility or Area	Type*	Firm Load MW	Firm Load Customers	Cause
01/04/93	**WSCC**	**Bonneville Power Administration**	**INT**	**514**	**n/a**	**Circuit breaker failure**
02/26/93	NPCC	Hydro-Québec	INT	1,200	40,000	Switching error
03/18/93	**WSCC**	**Western Area Power Administration — Lower Missouri Area**	**INT**	**60**	**13**	**Conductor fell**
04/03/93	NPCC	New Brunswick Power Corporation	UO	0	0	Line collapse
05/25/93	**MAAC**	**PECO Energy Company**	**UO**	**0**	**0**	**Line fault**
05/27/93	WSCC	PacifiCorp-East	INT	230	n/a	Protection system misoperation
06/04/93	**WSCC**	**BC Hydro**	**INT**	**730**	**n/a**	**Line trip**
06/27/93	WSCC	Tri-State G&T	UO	0	0	Line fault
07/02/93	**WSCC**	**PacifiCorp-East**	**INT**	**75**	**n/a**	**Line trip**
07/14/93	WSCC	PacifiCorp-West	INT	300	100,000	Line fault
07/20/93	**SPP**		**INT**	**300**	**n/a**	**Line interruptions**
07/22/93	**MAIN, ECAR, & SERC**		**UO**	**0**	**0**	**Heavy line loadings**
07/23/93	NPCC	New Brunswick Power Corporation	UO	0	0	Lightning
07/28/93	ECAR	Centerior Energy Corporation	INT	1,000	300,000	Storm
08/12/93	**MAPP**	**Dairyland Power Cooperative**	**UO**	**0**	**0**	**Line trip**
09/10/93	MAPP		UO	0	0	Line trip
10/04/93	WSCC	Seattle City Light	INT	11	1,800	Cable fault
10/10/93	WSCC	Bonneville Power Administration, Pacific Gas & Electric, PUD #1 of Cowlitz County	INT	713	n/a	Line fault
10/12/93	WSCC	Los Angeles Department of Water & Power	UO	0	0	Line fault
10/21/93	**NPCC**	**Hydro-Québec**	**INT**	**1,400**	**300,000**	**Line trip**
11/01/93	NPCC	Hydro-Québec	INT	715	70,000	CT explosion
11/02/93	NPCC	Hydro-Québec	INT	677	70,000	Ice
11/25/93	**NPCC**	**Ontario Hydro**	**UO**	**0**	**0**	**Line fault**
12/26/93	WSCC	Pacific Gas & Electric Company	INT	30	29,000	Line fault

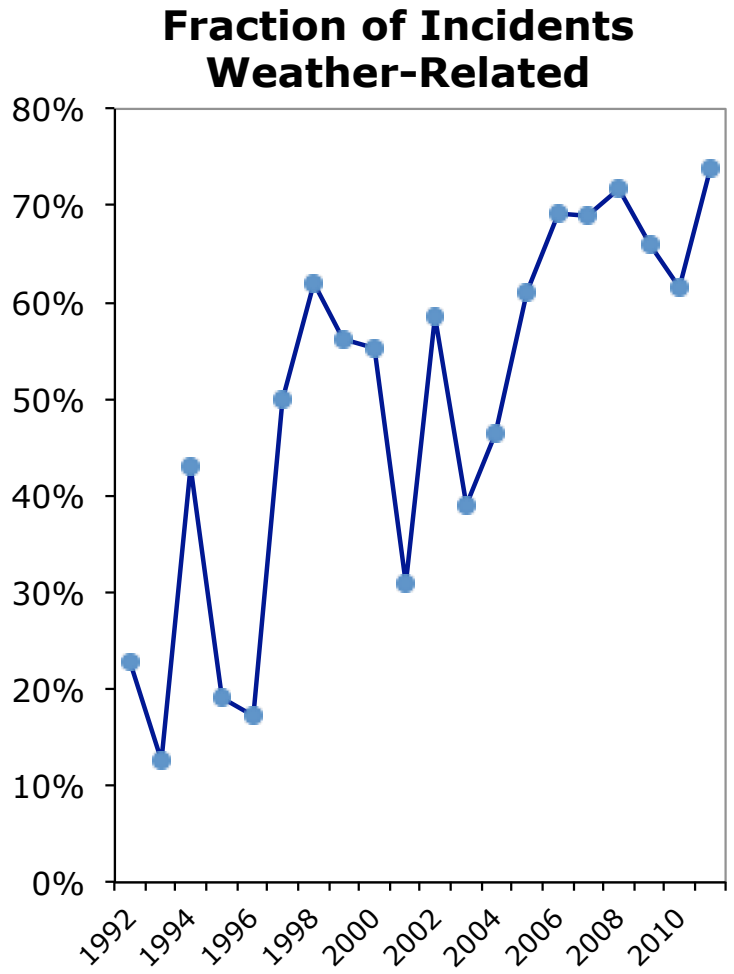
*Disturbances = INT, Demand Reductions = DR, and Unusual Occurrences = UO



Historical "Grid Disturbance" data from the US Department of Energy, Energy Information Administration. Form OE-417, “Electric Emergency Incident and Disturbance Report” (and before 1998 from the National Electric Reliability Council, Disturbance Analysis Working Group). Data include disturbances that occur on the bulk electric systems in the United States including electric service interruptions, voltage reductions, acts of sabotage, unusual occurrences that can affect the reliability of the bulk electric systems, and fuel problems.

Weather *vs* non-weather triggers





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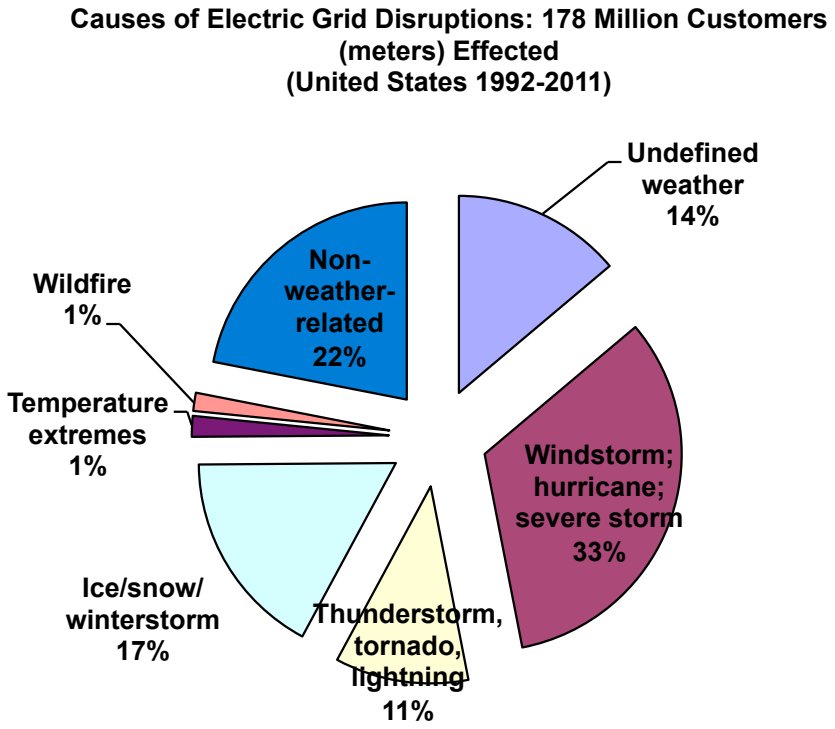
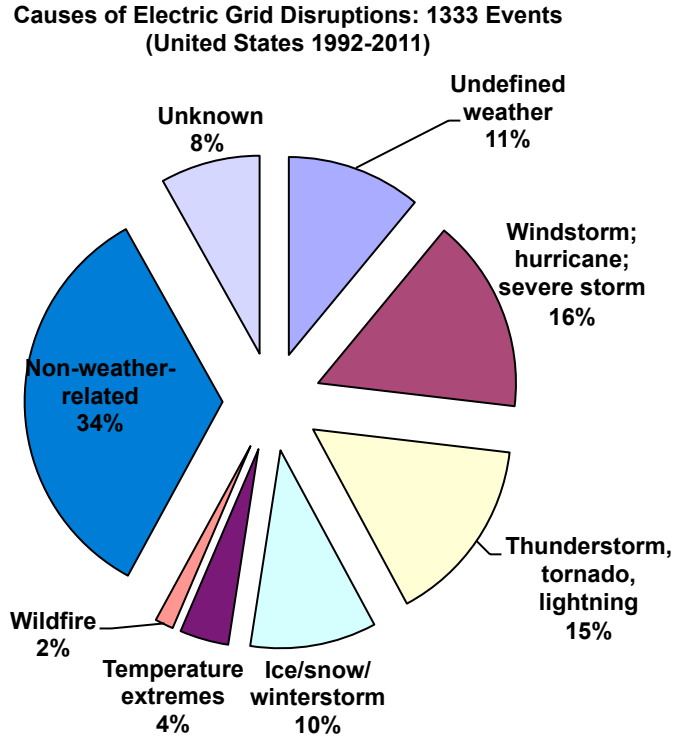
Impacts by trigger

66% (by number) are weather-related



78% (by customers) are weather-related



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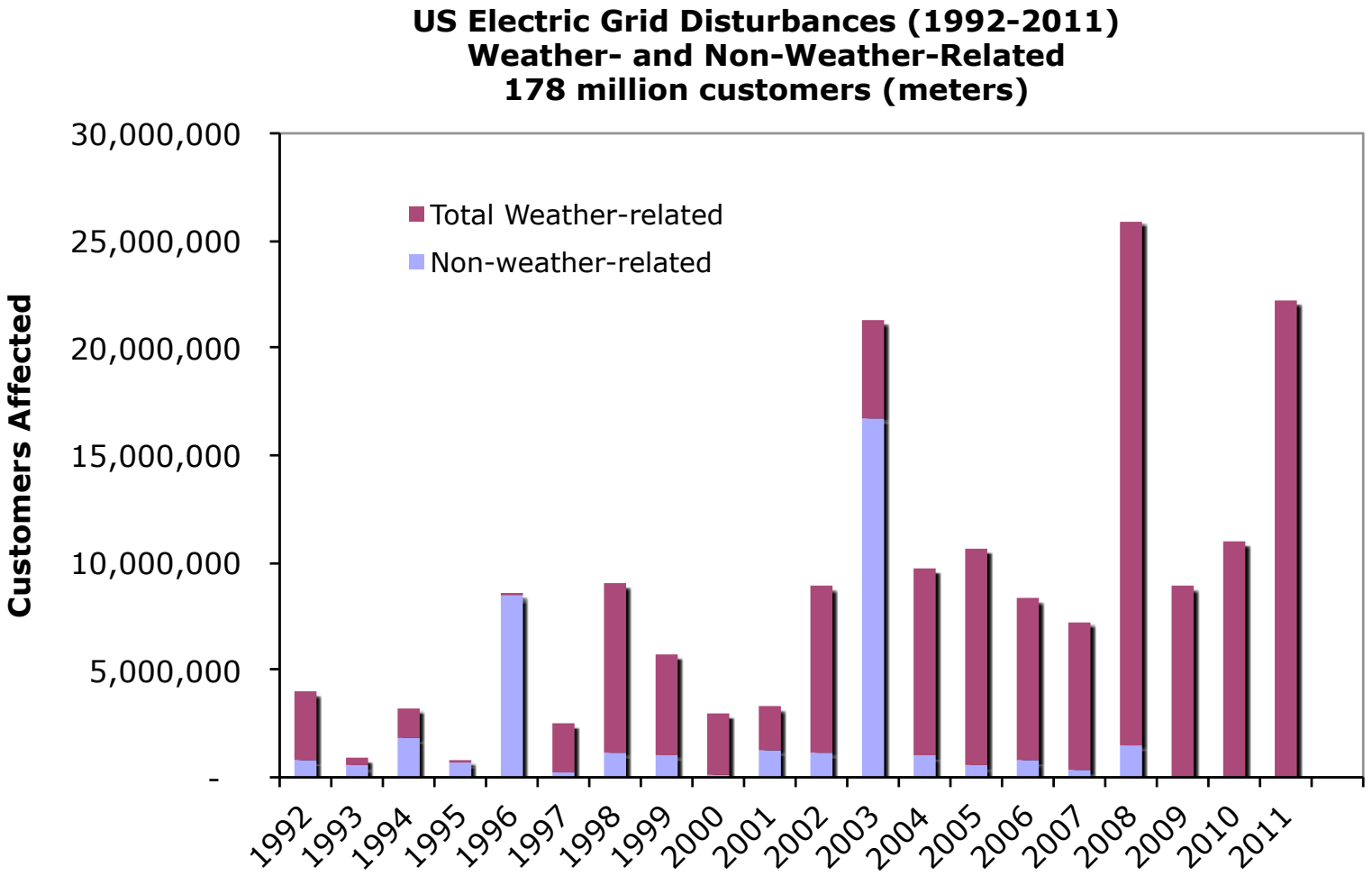
Customers affected



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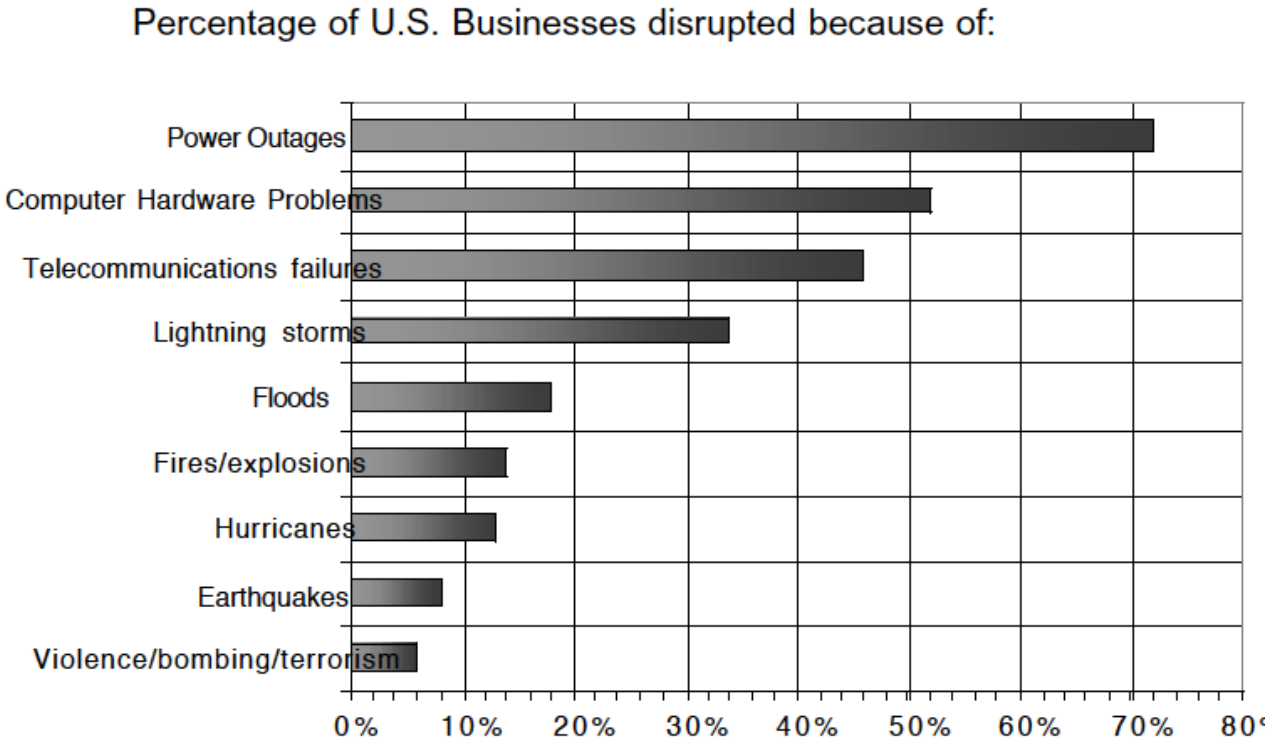
Business interruption

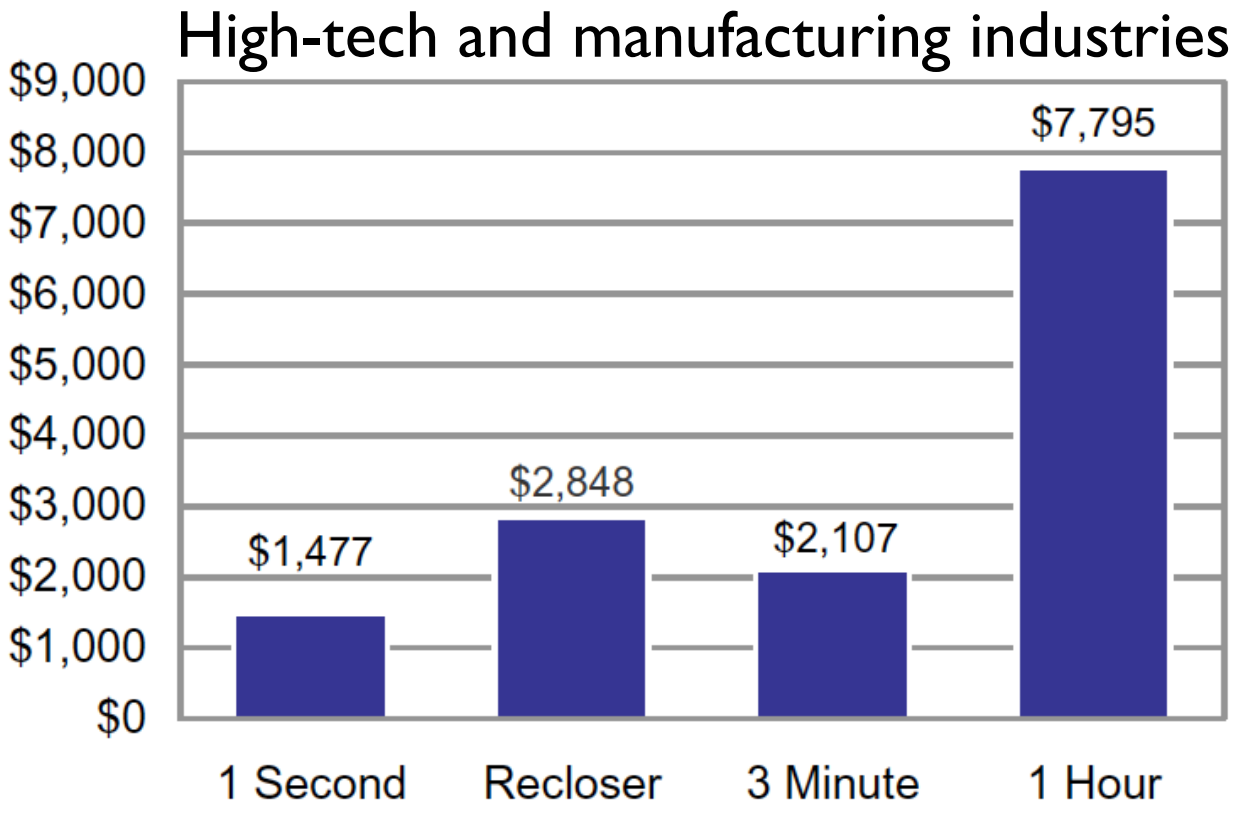


- BI comprises ~25% of insured losses following large natural disasters
- Northridge EQ: ~$4B of BI losses due to electricity outages
- Worst-case: losses can be $10s to100s of millions at a single location

Source: Rodentis, S. 1999. "Can Your Business Survive the Unexpected?" *Journal of Accountancy*. (February). 187(2). American Institute of Certified Public Accountants. http://www.aicpa.org/pubs/jofa/feb1999/rodetis.htm

Even brief events are costly

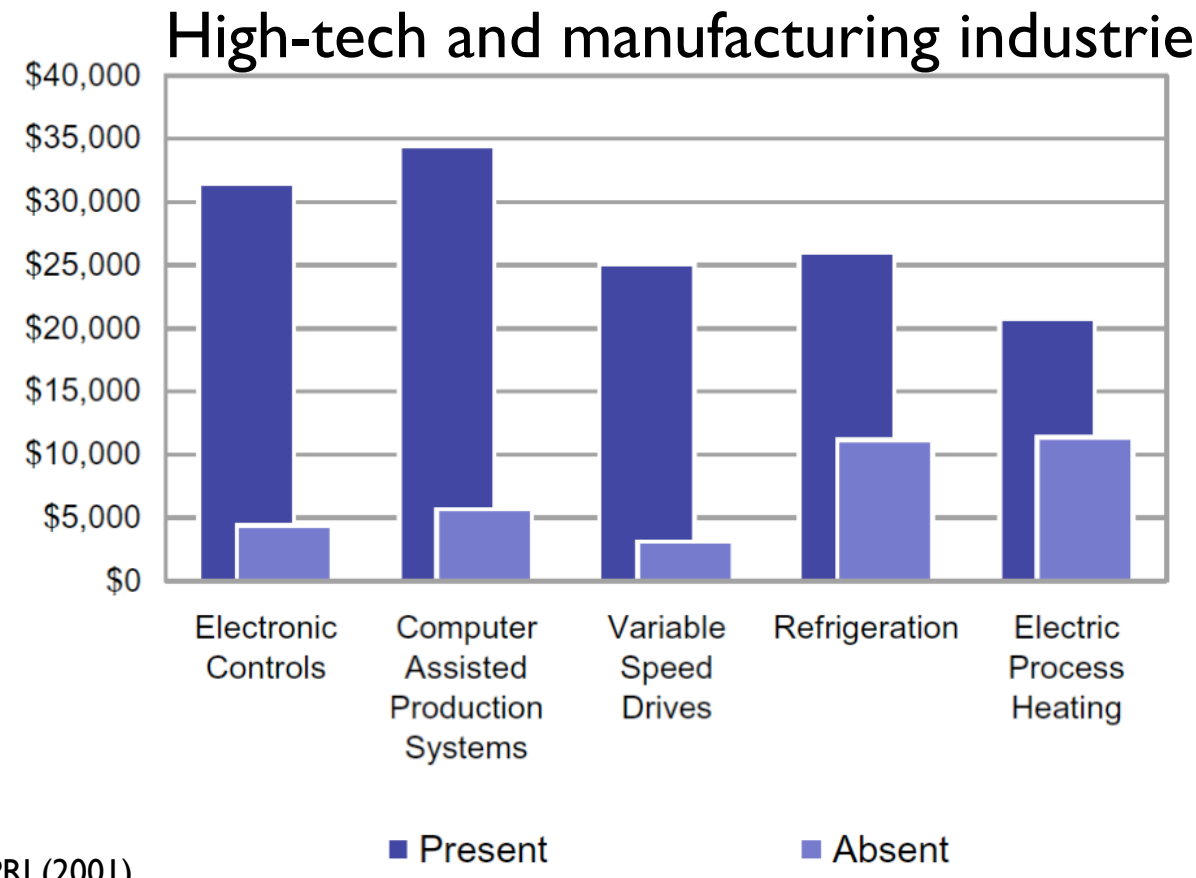
Figure 2-1: Average cost per outage by duration



Source: Primen/EPRI (2001)

Modernization has increased vulnerability

Figure 2-6: Average cost of one-hour outage by selected industrial equipment and processes



Source: Primen/EPRI (2001)

Anatomy of losses

Property Loss

- Power infrastructure
- Electronics and other downstream equipment damage
- Data loss
- Perishables (Food/pharmaceuticals, etc.) & materials loss (e.g. in manufacturing)

Business Interruption

- Processes or transactions (especially in energy-intensive industries)
- Supply chain disruptions
- Lost revenues for electricity suppliers
- Disrupted services from public utilities (water, transport, healthcare)

Thwarted disaster response efforts

- e.g., post-Katrina communications and pumping stations

Recovery costs: relief efforts; backup power, temporary housing, etc.

Litigation

Analytical considerations

- Majority of cost is an indirect consequence of direct damages
- Outages can be protracted (e.g., one-month following1994 Mississippi ice storm)
- Large areas typically affected, often impacting millions of people
- Costs spread across many parties: consumers, insurers ... and governments
- Cost sometimes captured in other stats; other times not
- Society's dependency on electricity is increasing ....

.... but the grid is increasingly frail/vulnerable

Insurance considerations

Insurance costs are often attenuated, or not incurred at all:

- Business Interruption (BI): Widespread lack of coverage (esp. "contingent BI") means that not all losses captured in stats. Deductibles denoted in time after event. 'Limits' cap payouts.

- Machinery Breakdown: May be caused by grid disturbances, lightning, etc. HSB's average claims $115,000 (late 1990s)

- Utilities often self-insure; sometimes with commercial reinsurance "layers" above

- Homeowner costs for perished food can be substantial (sometimes insured), but highly diffuse and perhaps impossible to statistically aggregate

Data gaps & research needs

- Current reporting is spotty, voluntary; ambiguous definitions
- Event trigger not always clear in the statistics
- Transmission (wholesale) & distribution (retail) grid both important
- Data often reported by utility territory, not by event or geography
- Insurance claims: ISO/PCS data exclude "small" events (<$25M) & 1000 claims

Readings

U.S. Energy Information Administration. "Electric Disturbance Events - Monthly and Annual Summaries." http://www.eia.gov/cneaf/electricity/page/disturb_events.html

Primen. 2001. "The Cost of Power Disturbances to Industrial and Digital Economy Companies." Prepared for the Electric Power Research Institute. 98pp.
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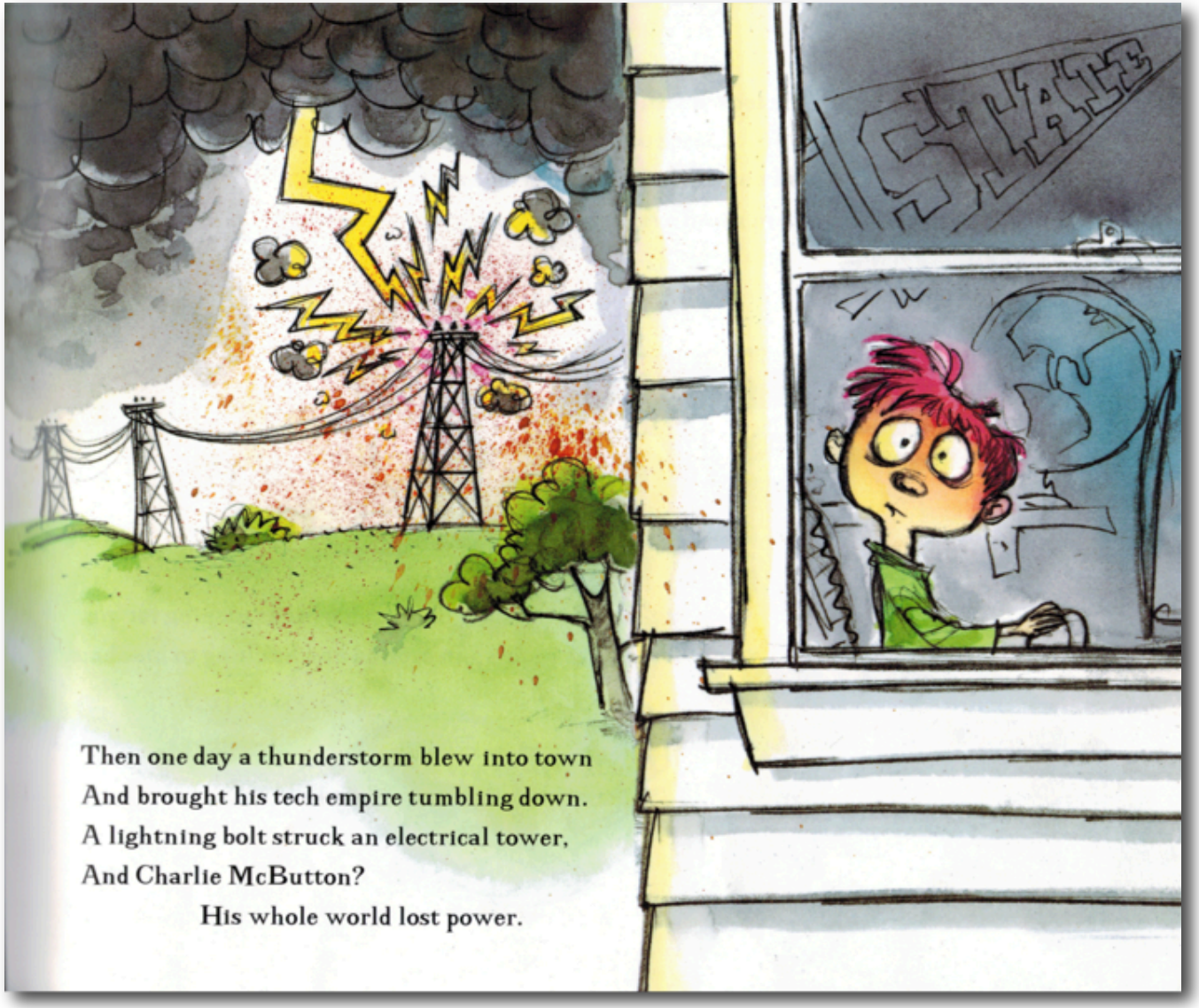
Correcting misinterpretations of the *U.S. Climate Impacts Study* assessment of grid disruptions - http://evanmills.lbl.gov/pubs/grid-disruptions.html



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